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Information Overload at the Tactical Level

(an application of Agent Based Modeling and Complexity Theory In a Combat Simulation)

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14. ABSTRACT

We address the appropriate level of information availability in a tactical setting at the small unit level. We examine this issue through a simulation utilizing Agent Based Modeling in a Complex Adaptive Systems Environment. The 'information level' we address is a function of communication range, sensor range, and agent location. By varying the communication capabilities (range) we effectively vary the information available for use by an individual agent in decision-making. We examine the effect of this varying information level on the combat outcome of the unit with a metric of a Loss Exchange Ratio.

Our initial results show that there is a significant relationship in terms of combat outcomes that exists between the range of the sensor and the range of the individual soldiers communications capabilities. If our communications capability outdistances our sensors we achieve a greater advantage in battle, and as the communications capabilities increase past this range we see an additional increase in our combat outcome - but only to a certain point - at which time the combat outcome deteriorates. In addition, through a 2 variable landscape analysis of fitness profiles we conjecture that the 'optimal' information level is actually a dynamic quantity determined in some part by what phase of battle a unit is operating in.

This work has potential to impact on the future design of combat simulations and hence our analytical abilities to model both new technology and changes to command and control structures.

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United States Military Academy
West Point, New York 10996

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**OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT #DSE-TR-02-04**

Major David M. Sanders, M.S.
Assistant Professor, Department of Systems Engineering

Colonel William B. Carlton, PhD
Program Director, Department of Systems Engineering

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Colonel Bill Klimack, Ph.D.
Director, Operations Research Center of Excellence

Approved by
Colonel Michael L. McGinnis, Ph.D.
Professor and Head, Department of Systems Engineering

August / 2002

The Operations Research Center of Excellence is supported by the Assistant secretary of the Army (Financial Management & Comptroller)

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Abstract

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About the Author(s)

Major David Sanders is an Assistant Professor and Research Analyst in the Operations Research Center and the Department of Systems Engineering at the United States Military Academy (USMA) at West Point, New York. MAJ Sanders graduated with a MS degree in Systems Engineering for the University of Virginia in 2000 and a BS in Systems Engineering form USMA in 1990. Major Sanders has served as an Air Defense Artillery Officer for 12 years in the U.S. Army and is currently serving in the U.S. Army as a Functional Area 49, Operations Research officer. Major Sander's research interests include complexity theory, Modeling and Simulation, and optimization theory.

Acknowledgements

This work is indebted to previous work done in concert with Project Albert, in particular to work done by Dr Andy Illachinski of the Center for Naval Analysis who created the model that we utilized. We are also indebted to previous work done by Major Larry Larimer and Major Rob Kewley who led the way in the Department here at USMA in the exploration of Agent Based Models.

Table of Contents

Paper for publication:

The following paper was submitted and published in the proceeding of the Society for Computer Simulation's Advanced Simulation Technology Conference, April 2002.

Information Overload at the Tactical Level

(an application of Agent Based Modeling
and Complexity Theory in a combat simulation)

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Keywords: Agent Based Model, Complexity, Combat Simulation, Value of Information

ABSTRACT

This paper explores the ability of an Agent Based Model (ABM) in a Complex Adaptive Systems (CAS) environment to replicate the effects of information overload at the small unit tactical level. Information overload occurs in combat when a decision maker receives too much information to process adequately in the time allotted, however our current ability to replicate that in a combat simulation is limited. In this paper we examine the capability of Agent Based Models to identify and measure the effects of information overload.

BACKGROUND

Previous attempts to examine the effects of information availability in combat simulations has only been done by scrutinizing the actions of the simulation participants – by analyzing whether or not they were able to identify crucial information and then act on that information by implementing changes in the simulated units actions. This human-in-the-loop analysis has provided important insights into the use and availability of information, and has even suggested changes to doctrine [Barris], but is critically dependent upon the ability of the human – and not all humans are created equally in their ability to process and filter information.

In this research we examine the ability of an Agent to make decisions based upon the information available, and then draw conclusions and insights based upon battle outcome (Loss Exchange Ratio). The 'information level' we address is a function of communication range, sensor range, and agent location. By varying the communication capabilities (range) we effectively vary the information available for use by an individual agent in decision-making.

Our results show that agent based models do show some deterioration in combat outcome when information overload occurs – thus that too much information is not only not helpful but is in fact detrimental. In addition the model we examined shows that the 'optimal' information level available to an agent is not a static quantity but is dynamic – it fluctuates depending upon the circumstances of the battlefield and the proximity of the enemy. While this is not an ear-shattering conclusion by any means (any 1LT could explain that the when you are in a close fight you want to pay more attention to what is within direct fire range and give less attention to the enemy rear), we do not have the ability in a accepted and utilized training simulation to demonstrate this effect without an analysis of the human-in the loop.

MODEL DEVELOPMENT

This work utilizes the model EINSTein developed at the Center for Naval Analysis [Ilachinski]. EINSTein gives us the ability to explore information issues with agents in a battlefield. For our analysis we fought five nine-man squads versus five equal ability nine-man squads on a 100 x 100 grid, and each squad has a separate battlefield area in for its primary engagement area. The goal of each squad is to reach a goal on the battlefield -essentially it is a game of capture the flag, but in this game the agents can injure or kill opponents. Agents are driven by 'personality vectors' which give them propensities to move toward or away from enemy or friendly forces and both the blue and red goals. The model gives us the ability to set many different parameters to control for the individual agents – the ones we will manipulate the most is the communications range – an agent with a communication range of n passes information about what it receives from its sensors to all friendly agents within an n x n box surrounding it. The sensor range s is an s x s box surrounding the agent where the agent can detect whatever is within the box – specifically terrain, friendly

agents, and enemy agents. The diagram below depicts the information that is available to the agent in the center (A_1):

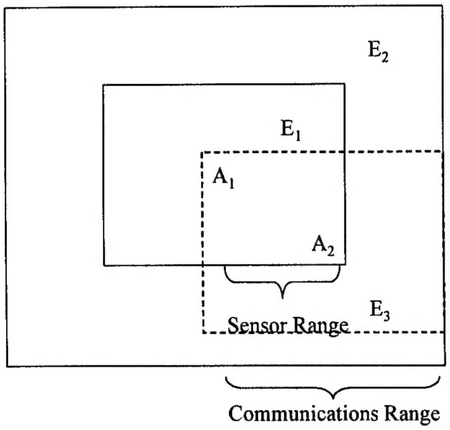


Figure 1: Information Level: In this diagram agent A_1 can 'see' agent A_2 and E_1 with his own sensors, but has no knowledge of Agent E_2. A_1 has information on agent E_3 because of information passed to him from Agent A_2, who detects E_3 from his sensors.

The amount of information an agent has at any time is therefore dependent upon both the sensor range and the communication range, where agents 'view' the amount of information detected by its sensors combined with the information that all friendly agents within his communications (commo) range detect. For our initial analysis we have held the sensor range constant (at 5 units) and vary the communication range – thus increasing or decreasing the amount of information available to an agent.

We examined values of communication range from n = 1 to n = 40 (at this range the agents sees approximately half of the battlefield), running each 'battle' for 150 time steps. and compared the results. We found significant differences existed in the Loss Exchange Ratio at the .005 confidence level between commo ranges of 1-4, 11-17, and above 20. The following data was generated:

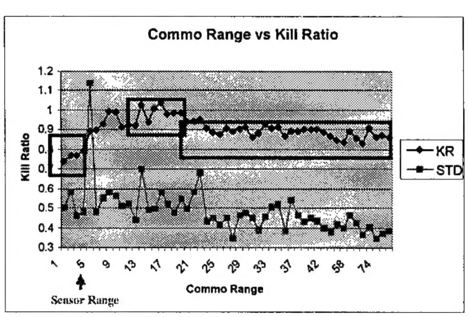


Figure 2: Results

Initial Analysis

The results show that as we increase the amount of information available the agent initially does not show improvement in battle outcome until his commo range outdistances his sensors - at that point the kill ratio begins to increase until a range of approximately 20 units, where we see a drop off in kill ratio. Thus we see a band of communication range which provides us with an increase in the Combat Loss Ratio. Though we will not claim we have found optimality (because we cannot support that conclusively) the ideal range in this situation seems to be around 16-18 units, with a lesser or greater communication capability not as effective.

This appears to indicate that the ABM is capable of identifying a non-linearity that exists in the communications range at certain points, and that information overload may actually occur in the model. On a practical note what occurs in the model as the commo range is extended is that the size of the area that information is used from to determine an agents actions – friendly and enemy agent locations – has become so large that the agent has available tactically irrelevant data in determining its course of action in the immediate battle. Thus the agent's decision may be improperly influenced by enemy or friendly units which are far away, outside of its tactical area of influence. In addition, it appears that the ability to communicate farther than the sensor range (n > s) provides a significant advantage to the agent.

Initial Conclusions

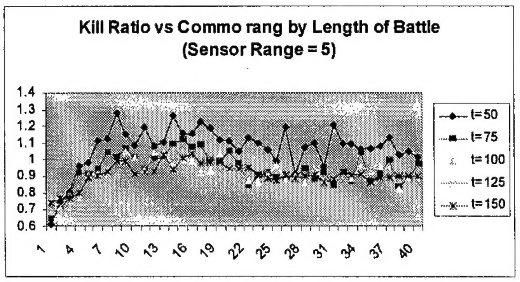
Agent Based Models are able to take many intangible items into account – such as morale, leadership abilities, and tactical information [Horne]. These items cannot be modeled in other combat simulations we use today – and these qualities may very well be at least as important in battle as weapons systems capabilities. Consider Operation Desert Storm – it would be difficult to argue that the morale and leadership of the Iraqis was less responsible for the outcome than was the superior weapons we deployed.

The potential ability of the ABM to represent such occurrences as information overload leads us to believe that

these models could well play a significant role in the future of combat simulations, especially when Command, Control, Communications, and Intelligence (C4I) issues are being studied.

SUBSEQUENT DOE

Following our initial analysis we considered the effect the length of the simulation had upon the data we collected. (The initial run was 300 replications for 150 time units for commo ranges of 1-40 units, incremented by 1 unit.) In attempting to explore the situation further, and to attempt to determine the cause of the decrease in effectiveness at a commo range of around 20 units, we ran the simulation again for lengths of 50, 75, 100, and 125 time units. All other parameters remained the same. The data we collected showed a similar overall pattern, as shown below:



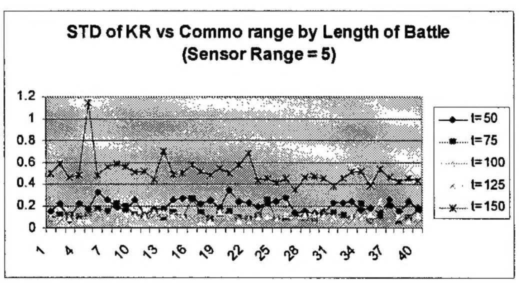


Figure 3: Data with varying length of battle

Subsequent Analysis

The data above shows that while the same general trend occurs, several observations can be made which appear important:

1) The initial gain in combat outcomes improves as communication distance increases at the fastest rate during a shorter simulation run (The t=50 line has the sharpest slope between commo ranges 1 and 10) This may be because at this shorter duration the units are more dispersed and at a time of 50 they main battle in still beginning. At a time of 75 the battle is slightly more advanced, and as we increase to a time of 150 the main battle is nearing completion.
2) The 'optimal' communications range is slightly higher at a shorter time (t=50) then gradually drops until t=125, where it appears to increase again slightly. This is significant because it possibly shows that the 'ideal' information level depends upon the length of the simulation run – and the length of the run determines the stage of the battle. A short run is akin to an initial meeting engagement, where a longer run puts the model int0o the main battle, while a still longer run ends after a pursuit is conducted. During each of these phases it would seem we would want a different information level, or area of interest, and it appears the ABM may be replicating that need.
3) The variance throughout the commo range is much higher at a time increment of t=150. This is likely due to the increased time that gives an advantage to the side which is ahead at that time of the battle – those who are winning at this point have a tendency to win big. The analysis of the variance and anomalies resulting from these simulations bears further scrutiny – often anomalous results are 'averaged' out when in fact these rare occurrences often can occur and have significant effect on a battlefield (for example, most combat models predicted a slow and costly fight in Desert Storm, when the reality of the eventual battle was staggeringly different).

To a more limited extent we have also examined the effect of sensor range on the metric of Combat Loss Ratio. We used a time of 100 units and ran sensor ranges of 3, 7, and 10 units and compared to our earlier model at a sensor range of 5:

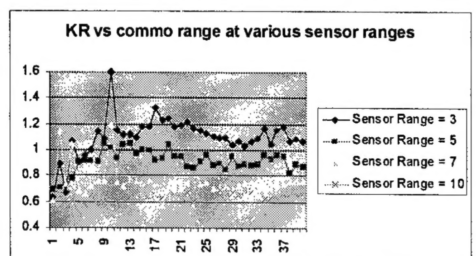


Figure 4: Data showing varying sensor range

As you can see, the same relationship exists at lower levels of the sensor range, but when sensor range is increased to 7, the communications range no longer seems to be significant. We believe one of the factors which causes this is that as sensor range increases the information that the agent receives is already great, and thus the agent is already experiencing a degradation due to information overload..

FUTURE WORK

Agent Based Models appear to hold great potential in their ability to more closely replicate human actions
We are continuing our research into Agent Based models in several areas:

1. Examining their ability to model new technology on the battlefield – such as the Future Combat system. This network of systems that will compose the FCS will undoubtedly use vast amounts of information – thus we need to have simulations capable of taking information use into account.
2. Considering the possibility of using agent based models in order to predict enemy contingencies. While the ABM may not be able to predict the exact course of action an enemy will take, it can, through repetition, show potential enemy actions and through time we may be able to refine our ability to develop probabilities of these actions from the model. This potentially shows the possibility of uncovering weaknesses in our own plans.
3. Investigate the ability of an ABM to 'learn', through genetic algorithms, in order to identify possible tactics, techniques, and procedures (TTP) which we may utilize with new technology. ABMs have shown the ability to develop their own TTPs through emergent behavior [Larimer] to include the use of 'covering forces' and encirclements.
4. We believe that these models have the capability to model training value. For example, we believe we can measure the effectiveness of 'learning' by training in a reconfigurable MOUT environment. By training the agent through repetition, genetic algorithms, and varied topography, we hope to be able to show quantitatively that a reconfigurable MOUT site provides a more highly trained force.

CONCLUSION

The endstate of ABM in the arena of combat modeling is yet to be seen, however we believe that it has great potential to not only increase the usefulness and effectiveness of these simulations but also to make them more cost effective. These types of models show the potential to model intangibles and information technology that our current systems lack. If we can develop better agents to fight in the simulations we could also decrease the number of people involved, thus lowering cost and freeing up valuable training time.

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Barris, "FBCB2 Dominant Maneuver Analysis" resented at the 38th annual U.S. Army Operations Research Symposium.

Ilachinski, A. EINSTein/ISAAC White Paper, http://www.can.org/isaac/WHITE.htm.

Horne, Gary, and Leonardi, Mary. *Maneuver Warfare Science 2001*, Defense Automated Printing Service, 2001.

Larimer, Larry R., and Carlton, William B., "Using Agent Based Modeling to Compute the Value of Information in Combat", Department of Systems Engineering Technical Report, US Military Academy, West Point, NY, 2 August 2001.

Briefing at ASTC:

The following briefing was conducted at the Society for Computer Simulation's Advanced Simulation Technology Conference, April 2002.

Information Overload at the Tactical Level

An application of Agent Based Modeling
and Complexity theory in a combat simulation

MAJ Dave Sanders
COL William Carlton

United States Military Academy

BACKGROUND

Janus Analysis of Information usage at USMA (98-99): Analysis involved examining what information Cadets utilized from Janus

- cadets ran Janus models
- Analysts recorded what info they utilized, or appeared to utilize while making decisions

– Conclusions:
  - Information usage important – those who utilized new information did better in battle

Barris – "FBCB2 dominant Maneuver Analysis" '00 MORS – Use of information as it develops to change plans can dramatically reshape the battlefield

'01-'02 CPT Harris (MS Thesis work at UVa): examining effect of information availability in Land Warrior on battle outcome

- cadets ran simulations
- Analysts recorded what info they utilized, or appeared to utilize while making decisions

– Results: Not yet published

'99 – warfare modeled as a CAS (Ilachinski, CNA)

Complex Adaptive Systems

- **What makes a system a CAS?**

  A system characterized by complex behaviors that arise as the result of numerous parts or agents.

- **Why is warfare a CAS?**
  - It consists of agents adapting to their environments
  - War is a hierarchy of complex systems nested one inside the other.
  - It is fundamentally uncertain and uncontrollable

- **Why should we model warfare as a CAS?**

Traditional Combat Simulations

- **Lanchester Equations**
  - fundamental, force on force
  - Most current combat simulations based on this approach

- 'Operator' Simulations:
  - Train system operators, Battalion and below decision makers
  - Semi-realistic combat, "human-in-the-loop"
- 'Process' Trainers:
  - Train Command and Control Staffs, Battalion level and higher
  - Results of simulation unreliable – staff/command development tool, not tactics/techniques evaluation

- Current simulations do not model intangibles

Previous USMA Analysis on use of ABM (predominantly EINSTein) (Larimer '01)

• The combat outcomes and effects "make sense" with respect to changes in input parameters.

• The Agents "learned" and "adapted" to find better behaviors that gave improved results over the initial behaviors used by both Blue and Red forces.

• Model outcomes indicate that changes in behavior (tactics and strategy) are necessary to fully exploit changes in technology.

• The model generated changes in Agent behavior that seem to reinforce proposed Force XXI operational concepts of battlefield dispersion and rapid reaction to changes in the enemy situation.

CONCLUSIONS

Larimer - AY01

- **ABM/CAS modeling demonstrates potential to**:
  - Measure value of information on the battlefield (including the effect of changes in behavior)
  - Help gain insight into how to adjust our behavior (tactics, strategy) to exploit changes in information technology

- **Potential Improvements ABM Models for Army Analysis:**
  - Fidelity: Increase sensor representation by adding the ability to vary sensor accuracy
  - Analytic Utility: Produce outputs which capture (for each agent):
    - Perceived enemy forces/locations by time
    - Actual enemy forces/locations by time
    - Perceived friendly forces/locations by time
    - Actual friendly forces/locations by time

USMA ABM Research Agenda

Long Term Objectives: Understand the impacts of complexity theory and ABMs for modeling information-age warfare in order to:

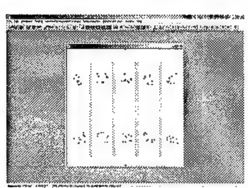
- Improve Combat Simulations in the US Army
  - > Improve Combat Model realism ***with respect to information capabilities***
  - > Reduce man-in-the-loop requirements
- Explore/develop strategies, tactics, TTPs for new technology
- Explore potential gains from C2 structures with the implementation of new information systems
- Improve the acquisition process through better evaluation of potential weapon systems and training aids

Short Term Objectives (AY02):

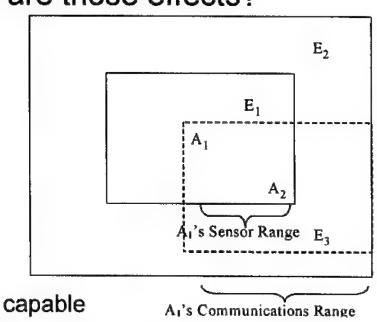
1. Evaluate the effects of Information Overload using ABMs in a tactical scenario **(MAJ Dave Sanders)**
2. Explore the 'validation' of ABMs by comparing results from EINSTein to results from JANUS **(CPT(P) Randy Klingaman)**

Tactical Level - Information Overload

Can an ABM show the effects of information overload in a tactical scenario? If so, what are those effects?



EINSTein Combat Simulation Model Developed at the Center for Naval Analysis

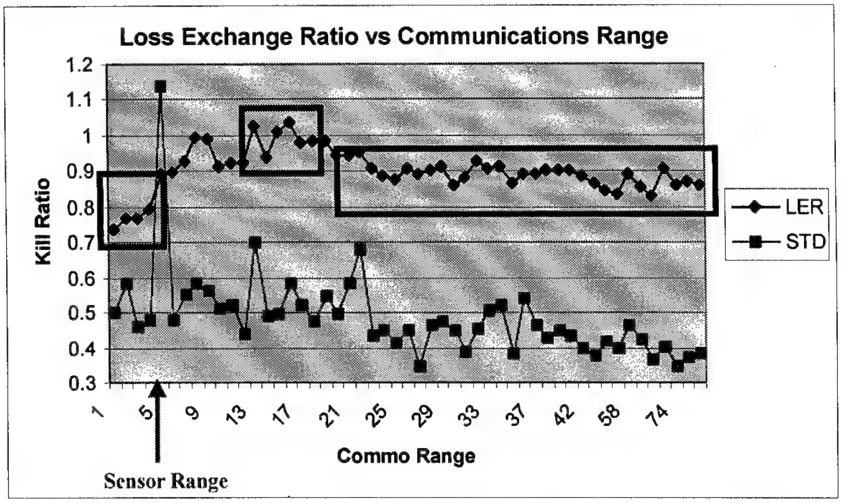


Scenario: 5 squads vs 5 squads, equally capable
- Vary communications capabilities of Red (we later added variation to run length and sensor ranges)
- Metric is kill ratio

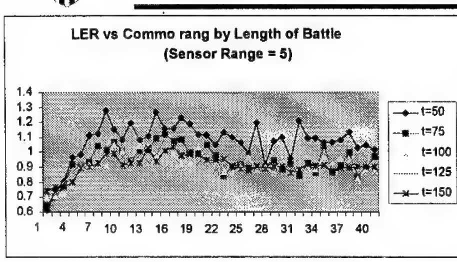
Hypothesis: Communications (and therefore information) will make combat outcome improve until information overload occurs, and then the outcome will either deteriorate or become highly variable.

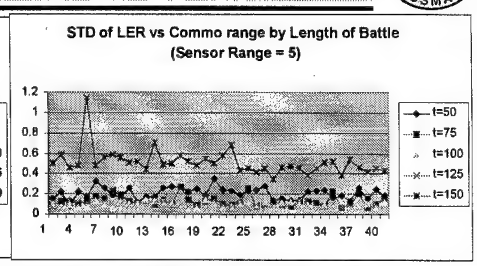
RESULTS

1. ***EINSTein ABM appears to replicate Information Overload***



Analysis





1. ***"Ideal" Information level is a dynamic quantity in the ABM (as it is in real combat)***
2. ***Increased information availability is most important during the initial stages of battle.***
3. ***The variance of combat outcomes is much higher at a longer run time irrespective of the communications range.***
4. **Increased organic sensor ability likely mitigate the need for additional information from other assets**

Perhaps the most remarkable result is that these phenomena can be modeled and measured using ABM.

Future Work

- Information Overload using MANA
  - (replicate previous work in a more dynamic model to see if the "ideal" information level is in fact dynamic and attempt to establish bounds and understand relationships)
- Modeling FCS in ABM (EINSTein/MANA)
- Model Terrorist scenarios using ABM
  - Utilize Palestine data and data analysis to create agents
  - Utilize ABM to analyze defensive measures or to predict future attacks
- Use Regression / Genetic Algorithms to "optimize" parameter settings
- "Automate" red actions in a combat simulation (JANUS?)
- NTC "validation" scenarios using larger formations and "mixed" platforms (M1/M2 vs T-80/BMP)

QUESTIONS?

Briefing at MORS:

The following briefing was conducted at the MORS Symposium, Jun 02.

Evaluating Information usage:
Information Overload at the Tactical Level

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Short Term Objectives (AY02):

1. Evaluate the effects of Information Overload using ABMs in a tactical scenario
2. **Generate potential COAs from ABM**

Traditional Combat Simulations

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  - Most current combat simulations based on this approach
- 'Operator' Simulations:
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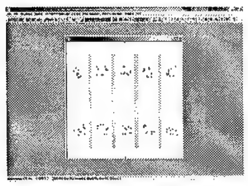

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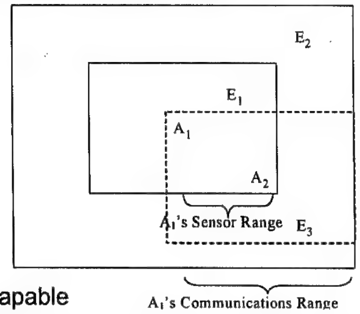

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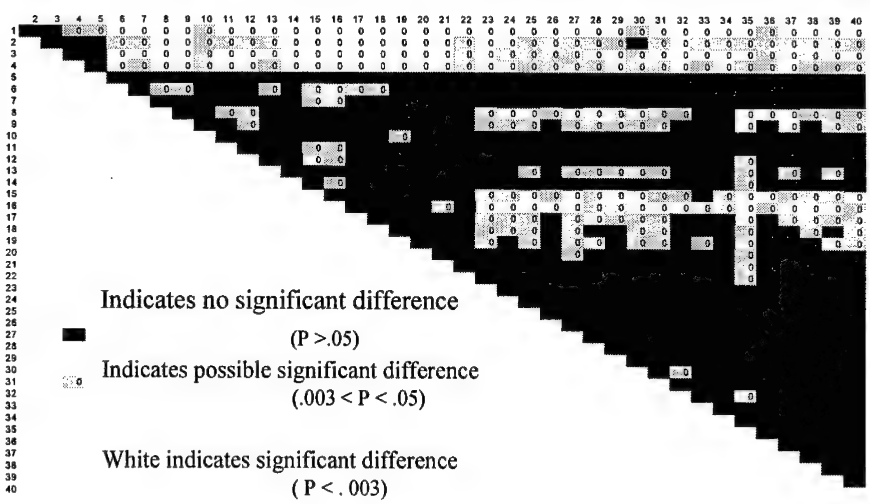
Outcome of experiment



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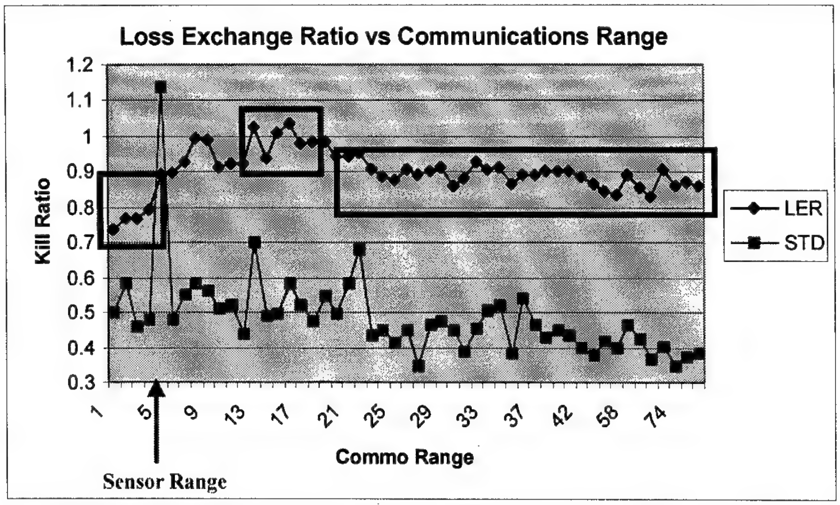
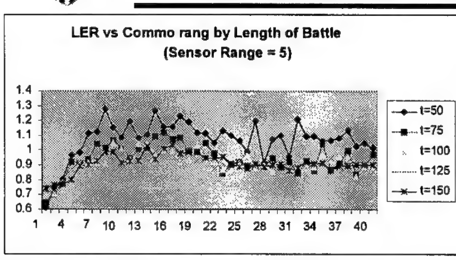
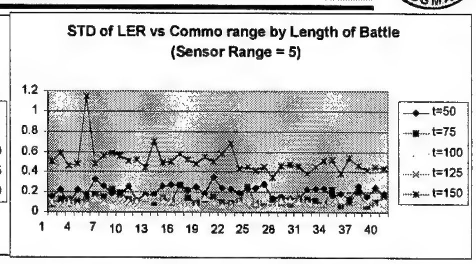


Analysis





1. ***"Ideal" Information level is a dynamic quantity in the ABM (as it is in real combat)***
2. ***Increased information availability is most important during the initial stages of battle.***
3. ***The variance of combat outcomes is much higher at a longer run time irrespective of the communications range.***
4. **Increased organic sensor ability likely mitigate the need for additional information from other assets**

Perhaps the most remarkable result is that these phenomena can be modeled and measured using ABM.

Future Work

- Generate enemy COAs from ABM
  - "Automate" red actions in a combat simulation (JANUS?)
  - Utilize as planning aid for COA development / analysis
- Modeling FCS in ABM (EINSTein/MANA)
- Model Terrorist scenarios using ABM
  - Utilize Palestine data and data analysis to create agents
  - Utilize ABM to analyze defensive measures or to predict future attacks

COA generator concept for use as planning facilitator

- generate digital map
- Position friendly assets in current locations
- Input friendly COA
  - Assign parameters to duplicate intended COA
- Assess friendly COA against potential enemy COAs:
  - Input enemy data / locations
  - Run excursion of enemy data sets – predict enemy parameters for 3-4 (?) local optimal – rerun
  - generate enemy COAs from final data
    - generate scheme of maneuver, force structure, and timeline
    - Predict most likely, most dangerous?
- Consider insights from simulation in planning/operational factors

Automate enemy COAs in Janus

- Load digital map into scenario generator from Janus
- Position friendly assets in current locations (output of database) (assign agent parameter values based upon doctrine)
- Generate enemy COAs:
  - Input current enemy data / locations (database)
  - Run excursion of enemy data sets – predict enemy parameters for 3-4 local optimal – rerun
  - Consider coevolution of tactics?
  - generate enemy COAs from final data
    - generate scheme of maneuver, force structure, and timeline
    - Use most likely, most dangerous?
- Consider insights from simulation in planning/operational factors

QUESTIONS?

Bibliography

See paper for publication for references.

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